Verification of Military Gas Mask Technology

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INTRODUCTION

Military personnel wear gas masks for protection against a chemical and biological assault. The recognized potential global threat from chemical and biological agents demands that effective defense measures be taken. An important part of this defense strategy is the testing and verification that assures secure gas mask fits. The M41 was developed for the military to field-test its protective equipment on the person using the protective devices. The Army determines the gas mask fit quality by measurement and comparison of the ambient aerosol concentration outside of the fitted masks to the aerosol concentration inside. The particles can identify both leaks in the mask and inefficiencies in the filters. This technology is believed to provide a complete diagnostic of the integrity of the mask, the filter and the fit on the individual.

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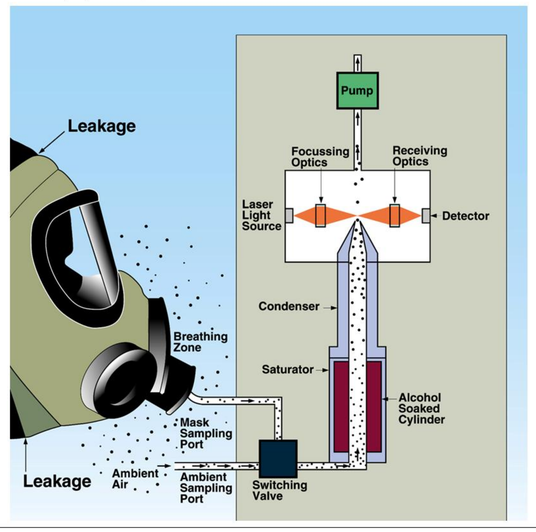
M41 fit tester and military gas mask

Courtesy of TSI, Inc.

The M41utilizes ambient atmospheric aerosol as a challenge to the gas mask. This field instrument determines the the total leakage or particle penetration into the mask by comparing the particle concentration outside the mask to that found inside the mask. The particles enter the sampling port and are drawn through a column saturated with alcohol vapor. Then the particles pass into a cooler region, the condenser, where alcohol vapor condenses and grows droplets. The droplets are large enough to detect by light scattering. Pulse counting provides the number of particles per volume of air. This fit test integrates all leak mechanisms possible when the mask is employed. It will measure small pin hole leaks in the material, improper fitting to the face due to facial contours and malfunction of the filter.

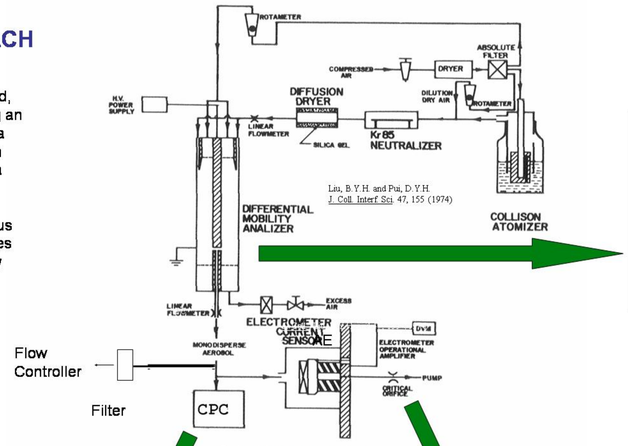


Schematic of M41 and the fit test procedure.

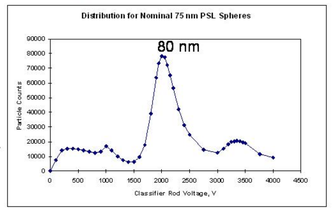
Courtesy of TSI, Inc.

EXPERIMENTAL APPROACH

80 nm polystyrene particles are aerosolized, charge neutralized and notch filtered using an aerosol mobility classifier. This produces a continuous stream of monodisperse 80 nm aerosol with a single electronic charge at a constant concentration. The aerosol Is used to challenge the CPC and the concentration is determined by a continuous reading Aerosol Electrometer that measures the charge current form the aerosol and by quantitative filter collection followed by scanning electron microscopy (SEM) and image analysis.



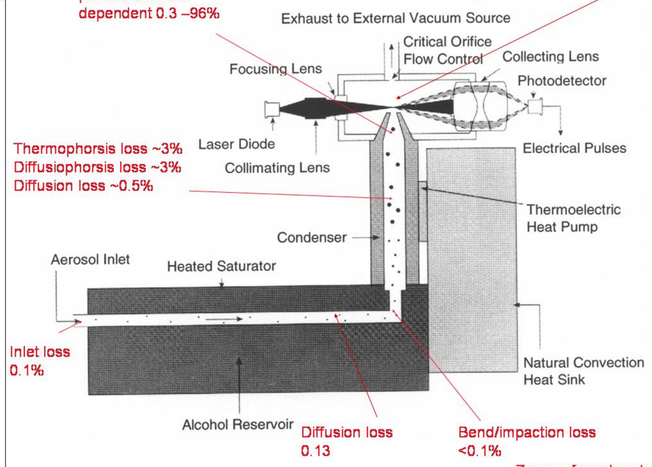
Mobility Classifier and CPC
Sample: 80 nm polystyrene spheres in 15M ohm water



The diameter of the particles that are delivered by the mobility classifier is controlled by the voltage applied in the instrument. The plot shows number of particles as a function of the applied voltage. The large central peak corresponds to the 80 nm polystyrene aerosol. The challenge aerosol was produced with the voltage setting on the mode of the peak.

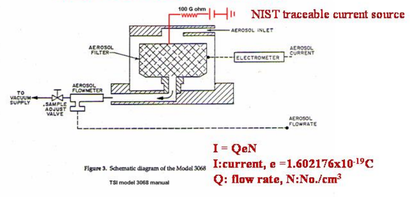
Coincidence counting concentration dependent ~10% at 10,000/cm^3

Loss in nozzle particle diameter dependent 0.3 –96%



Zones of most probable particle loss were identified and existing aerosol capture mechanism were employed to model the particle loss in the CPC.

Aerosol Electrometer



$I = QeN$
I:current, e =1.602176x10^{-19}C
Q: flow rate, N:No./cm^3

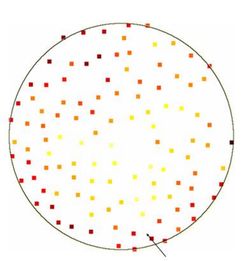
Figure 3. Schematic diagram of the Model 3068 TSI model 3068 manual

The AE determines the particle concentration by measuring the charge current produced by the single charged airborne particles. These currents are ~pA in magnitude and difficult to generate and measure. The AE was calibrated to a NIST traceable current standard.

Number Concentration by Microscopy

Particle count + Flow rate + Field size

SRM 484d SEM Magnification Artifact Traceable to Linescale Interferometer



field of view

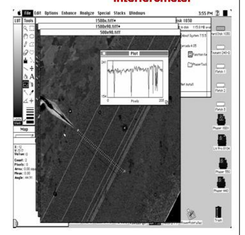
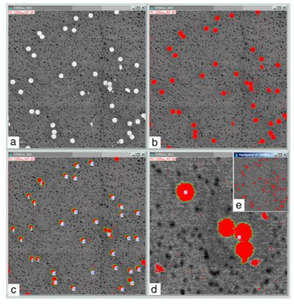
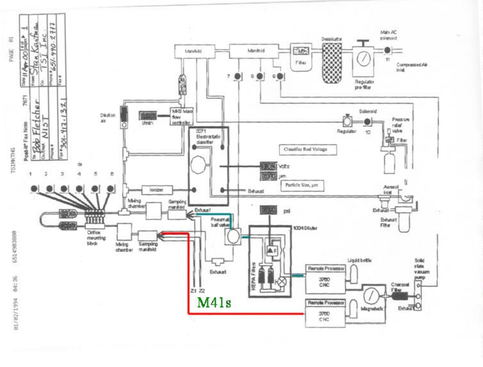


Image Analysis
(polystyrene latex beads on polycarbonate)

a. Original image
b. Thresholded
c. Blobbed image with discrimination
d. 4X enlargement
Of blobbed image

Software:
LISPIX
http://www.nist.gov/lispix
NIH Image





PROBLEM

The M41s are tested and verified by the U.S. Army Test, Measurement, and Diagnostic Group using a fit-test calibration stand (test stand). The components of the test stand are an aerosol generator, aerosol electrical charger, a mobility classifier to produce monodisperse 80 nm diameter aerosol, an aerosol dilution system and two condensation particle counters (CPCs). The test aerosol concentration range is 100-10,000 particles/cm.^{3} The aerosol concentrations are determined by the calibrant instruments, two TSI, Inc model 3760a CPCs.

There are no aerosol concentration standards for the CPCs nor are there certified reference materials available for aerosol concentration standardization. The measurement process currently has no links or traceability to a standards granting organization. The U.S. Army Test, Measurement, and Diagnostic Equipment Activity (USATA) requires the development of an aerosol concentration standard method, traceable to the National Institute of Standards and Technology.

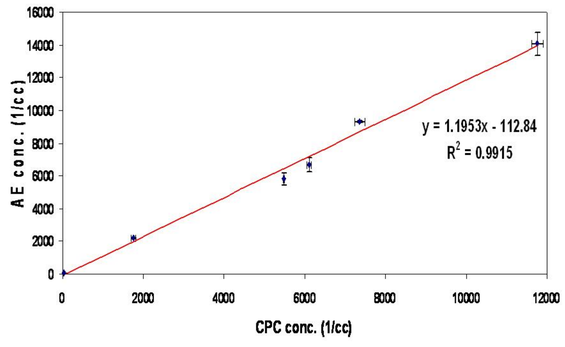
OBJECTIVE

The objective is to provide measurement assurance to the U.S. Army for their gas mask fit-test method by verifying the accuracy of the aerosol concentration measurement integral to this test method.

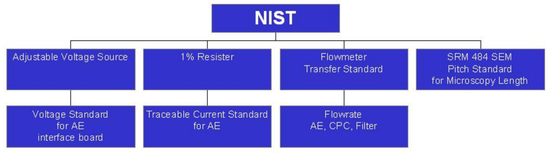
RESULTS

SEM image analysis is the primary measurement technique. The measurements obtained from the AE have been made traceable to NIST by developing a NIST traceable current (pA) source to calibrate the AE. Preliminary measurements of the particle concentrations obtained by the CPC and the AE operating on the same monodisperse aerosol over the range of approximately 100 –12,000 particles/cm^3 are presented below.

Comparison of Particle Concentration Measurements for the CPC and the AE (preliminary)



NIST TRACEABILITY



Impact: This verification and development of a standard method would enable the accurate calibration of Condensation Particle Counters that are currently used to calibrate M41 Protective Assessment Test Systems (PATS) for the Army. The Army serves as the sole calibration agent for the tri-services.

NIST CENTENNIAL 100 1901-2001

NIST Analytical Microscopy Group

ACKNOWLEGEMENTS

The authors would like to acknowledge the U.S. Army for support of this project.